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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Retractable Noise Suppressor for Jet Propulsion Engines

We, BOEING AIRPLANE COMPANY, a corporation of the State of Delaware, United States of America, of 7755 East Marginal Way, Seattle, King County, State of Washington, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to noise suppression devices for jet propulsion engines of the gas stream thrust reaction type. The invention is herein illustratively described by reference to the presently preferred forms thereof; however, it will be evident that certain modifications and changes therein with respect to details may be made within the scope of the invention.

Certain noise suppressor devices for jet engines and the general theory by which they operate are described in the following co-pending patent applications:—

No. 3,318/57. (Serial No. 831,152).
No. 2,502/57. (Serial No. 835,134).
No. 3,149/57. (Serial No. 841,580).

In general, the present invention achieves jet engine noise suppression by the same basic approach as that employed in the above-cited applications, namely, that of dividing the discharge stream into a plurality of separate or branch streams at the nozzle exit. This division of the main jet into a number of smaller jets, particularly when these are spaced apart about the periphery of the nozzle exit decreases objectionable noise in two ways. First, it reduces the total noise level, and, secondly, it shifts much of the residual noise to higher frequencies at which the effect on the human ear is less noticeable.

When the main discharge stream from a jet engine is divided into a plurality of separate streams at the nozzle exit a certain reduction of nozzle efficiency takes place. This is due to the obstructive effect and friction losses incurred by the stream dividers. In some applications the thrust loss is not serious and the stream dividers are a fixed and integral part of the nozzle. In other applications, however, with which the present invention is primarily concerned, there are times when full engine efficiency obtained only with an unbroken circular or similar regular exit configuration, is necessary and is more important than noise suppression. It is therefore desirable in such instances to be able to convert the nozzle back and forth between a setting for efficient noise suppression operation and a different settting for maximum thrust operation without regard to noise level.

With the foregoing in view the present invention is directed broadly to the provision of improved noise suppression nozzles for jet propulsion engines, having retractable noise suppression elements, and more specifically having an adjustable nozzle exit opening in combination with retractable stream divider elements disposable in the discharge stream at the nozzle exit. A related objective is the co-ordination of the retraction and extension movement of the stream divider elements with movement of orifice elements by which the area of the nozzle opening is varied, to the end of establishing approximately the same exit area with the stream divider elements extended to their noise suppression setting as when these elements are retracted to gain thrust. In this way the nozzle delivers the maximum thrust of which it is capable in the noise suppression setting, and the greater maximum thrust in its alternative or cruise

setting. Such a nozzle adapted for thrust reversal provisions constitutes a further object.

Other objects are to provide specially formed stream divider elements which are efficient to mix the jet gases with ambient air with minimum turbulence noise; to provide noise suppression nozzles of a compact form meeting the foregoing objectives; and to provide such nozzles of a practicable and reliable construction wherein the combined functions of stream division and exit area compensation may be effected with comparatively few and simple components readily applied to existing basic engine types.

In its overall combination aspects, therefore, features of the invention reside in the disclosed combinations of a plurality of stream divider elements adapted to be extended transversely in relation to the path of discharge through the nozzle exit and to be retracted therefrom, and relatively movable duct-forming orifice means operable in conjunction with such stream divider elements to vary the exit opening compensatively so that the net area thereof is at least approximately the same with the stream divider elements extended as otherwise. Certain other features reside in the preferred forms of divider elements of which two specific types are herein disclosed. One is in the nature of a tab, retraction of which entails removal from the orifice opening to lie parallel to a duct wall or to be withdrawn from the duct altogether. The second type comprises pairs of oppositely extended vanes, retraction of which entails drawing them together into faired relationship with their support occupying a position extending at all times across the orifice opening. Detailed features reside in variations of the tab and vane construction and in the means of mounting, supporting and actuating the same, particularly in conjunction with the means for varying nozzle opening compensatively. Still other features reside in the combination wherein the relatively movable duct-forming members by which nozzle opening is varied comprise a nozzle ring or sleeve and within it a nozzle tail cone, with means for effecting relative longitudinal movement between the sleeve and tail cone, so that by virtue of the cone taper angle a variation takes place in the restriction between the two at the exit end of the sleeve.

These and other features, objects, and advantages of the invention will become more fully evident from the following description thereof by reference to the accompanying drawings.

Figure 1 is a rear perspective view of a jet propulsion engine discharge nozzle embodying the invention in one form employing retractable stream divider tabs and an orifice with variable opening, the view showing the tabs extended, the exit diameter enlarged and thrust reversal means retracted.

Figure 2 is a fragmentary longitudinal sectional view at a larger scale showing the discharge nozzle of Figure 1, with the parts in the same position as in that Figure.

Figure 3 is an end view based on Figure 2.

Figure 4 is a rear perspective view similar to Figure 1 but with the tabs retracted and the exit diameter reduced.

Figure 5 is a view similar to Figure 2, but with the parts positioned as in Figure 4.

Figure 6 is an end view based on Figure 5.

Figure 7 is a view similar to Figure 1, but with the thrust reversal means extended into operative position.

Figure 8 is a view similar to Figure 2, but with the parts positioned as in Figure 7.

Figure 9 is a fragmentary rear perspective view of one of the tabs and associated orifice-defining leaves, together with actuating means for both as in the embodiment of Figures 1 to 8, inclusive.

Figures 10, 11 and 12 are views similar to Figure 9 showing different modified types of retractable obstruction tabs according to further features of the invention.

Figure 13 is a fragmentary longitudinal sectional view similar to Figure 2 but showing an embodiment featuring a modified mounting and actuating arrangement for the obstruction tabs, the view showing a tab extended and the exit diameter enlarged.

Figure 14 is a fragmentary rear and end view based on Figure 13.

Fig. 15 is a view similar to Figure 13 and of the same embodiment, with the tab retracted and the exit diameter reduced.

Figure 16 is a fragmentary longitudinal sectional view of a modified discharge nozzle incorporating the invention and featuring a movable tail cone arrangement for varying effective orifice exit diameter in relation to tab position, the view showing the tabs extended and the tail cone retracted to increase the effective exit diameter.

Figure 17 is a view similar to that in Figure 16, but with the tabs retracted and the tail cone extended.

Figure 18 is a rear perspective view of a jet engine discharge nozzle incorporating still another embodiment of the invention particularly with relation to the type of retractable stream divider elements employed, which in this instance comprise pairs of vanes movable between laterally extended, stream dividing position and retracted position faired with their supports in the nozzle discharge stream.

Figure 19 is a longitudinal sectional view with part broken away, showing the nozzle

of Figure 18 in its cruise or maximum thrust setting.

Figure 20 is a view similar to Figure 19 with the vanes in extended position and the vane assembly projected rearwardly to the orifice exit, the view showing the exit diameter enlarged.

Figure 21 is a simplified view showing one of the pairs of vanes and their support viewed radially of the nozzle, with the vanes retracted.

Figure 22 is a view similar to Figure 21 but showing two pairs of vanes and their supports, with the vanes extended.

Referring to the embodiment shown in Figures 1 to 9, inclusive, it will be evident that the main body of the jet engine is omitted from the drawings, which illustrate only the discharge nozzle portion thereof. As shown, the engine outer cowl 10 terminates rearwardly in a ring section comprising a plurality of alternatively overlapping and overlapped leaves 12 sometimes referred to in the art as "turkey feathers" which are pivoted at their forward edges about transverse axes extending generally tagentially to the periphery of the cowl where it is joined by the leaved ring section. Thus, as shown in Figure 2, the leaf 12 is pivoted on the pin 14 in suitable journal elements carried by the cowl edge. A crank arm 16 projecting inwardly from the forward edge of the leaf and rigid with the leaf is connected by a spring 18 to an anchor element 20 on the inside of the cowl for urging the leaf 12 into an inwardly swung position. The position which it assumes under force of the spring and the relative airstream is established by contact between a cam 22 on the leaf and a follower wheel 24 on a support 26. The latter is carried by a link member 28 which is provided with a straight longitudinal slot 30 engaged for guidance by stationary rollers 32 and 34 spaced apart lengthwise of the slot and fixed to the tube 36 comprising one of the nozzle duct-forming members. The other nozzle duct-forming member in this embodiment comprises the rearwardly tapered tail cone 38 which projects somewhat beyond the nozzle exit and extends forwardly to merge with a central cylindrical island member 40 mounted within the engine. In this embodiment of the invention the provision of a tail cone in the engine is optional.

The cowl 10 and ring section comprising leaves 12 form a protective outer housing for certain engine components, including actuating mechanism for the noise suppression elements of this embodiment of the present invention and for the leaves 12. Also, such cowl furnishes a protective housing for a rearwardly projectable thrust reversal sleeve 42 of a known type. Normally, this sleeve is drawn forwardly into its retracted, inoperative position and the leaves 12 form a rearwardly convergent cowl section. However, as shown in Figures 7 and 8, rearward extension of the thrust reversal sleeve 42, effected by means not shown, causes a longitudinal surface of the sleeves to engage the cam 22 and force the leaves 12 outwardly sufficiently to permit rearward projection of the sleeve into thrust reversal position. Sleeve 42 is guided paritally by contact of a longitudinal inside surface thereof, 42*a*, with the roller 24. In the thrust reversal setting, automatically projected jet diverger elements 44 are disposed across the end of the discharge opening of the nozzle, beyond the tail cone 38, to deflect the hot gases outwardly toward the forwardly and outwardly curved louvers 42*b* situated in opposite sides of the thrust reversal sleeve as shown. This previously-known thrust reversal mechanism is illustrated herein only for purposes of background and in some cases its incorporation, or the incorporation of any thrust reversal means for that matter, in a jet engine incorporating the present invention is optional.

The rear edge of the cylindrical exhaust tube 36 is located somewhat forwardly of the rear edge of the leaved cowl section 12. The nozzle discharge orifice is formed between the tail cone 38 and a contractable and expansible leaved extension ring 36^1 of the tube 36. Such extension is formed by leaves 36^1a pivotally mounted at regularly spaced intervals around the rear end of tube 36, and overlapped by intermediately situated leaves 36^1b similarly mounted on the end of the tube. As will be evident the orifice exit may be expanded by outward swinging of the leaves to the position shown in Figures 1 and 2, for example, and contacted by inward swinging of the leaves to the position shown in Figures 4 and 5. Longitudinal edge flanges on the leaves 36^1b bear slidably against the outside surfaces of the overlapped leaves 36^1a, whereas similar outwardly directed flanges on the longitudinal edges of the overlapped leaves 36^1a bear slidably against the inside surfaces of the adjacent leaves 36^1b. These flanges form a seal and, as shown in Figure 9, provide a positive means limiting outwardly swinging of the leaves to the expanded condition of the ring section 36^1. Hook-like retainer elements 35 on the projecting ends of the leaves 36^1a hold the adjacent leaves 36^1b against them in all positions of the former.

Pivotally mounted on a transverse axis at the rear edge of each of the overlapped leaves 36^1a is a retractable stream divider or obstruction element in the form of a trapezoidally shaped tab 46. The tab is of generally elongated form. The broader of its two ends is connected to the leaf 36^1a and for that purpose carries sleeve elements 48 aligned transversely of the nozzle with

a sleeve element 50 mounted on the end of the sleeve 36^1a. A hinge pin 52 extends through the aligned elements 48 and 50. The tab 46 is thus mounted for swinging between retracted position, projecting forwardly of the nozzle and lying flatly in contact with the inside surface of the supporting leaf 36^1a as shown in Figure 5, and extended position directed transversely of the nozzle discharge in substantially perpendicular relationship with the supporting leaf, as shown in Figure 2.

In this embodiment as well as in the others herein disclosed it is preferred that the stream divider elements extend inwardly toward the nozzle axis from a location substantially at the outside periphery of the exit so as to prevent a sheath of discharge gases at the exit which would surround the branch streams formed by the stream dividers and would thereby obstruct free inflow of surrounding air into the spaces between the separate branch streams.

In order to actuate the tab 46 between these positions a crank arm 54 is rigidly connected with the base of the tab and forms an obtuse angle to the plane of the tab, projecting generally outwardly in relation to the nozzle. This crank arm is connected pivotally to one end of a rod 56, the opposite end of which is pivotally connected to the rearwardly projecting end of the guided link 28. An hydraulic jack 58 or other suitable actuator connected to the longitudinally movable link 28 moves the connecting rod 56 lengthwise of the nozzle. In the forwardly drawn position of this connecting link, as shown in Figure 2, the crank arm 54 is swung forwardly toward an angular position approaching alignment with the rod 56, and in this position of the link and rod 56 a protuberance 56^1 on the inner side of the rod generally intermediate its ends bears against the outside face of the supporting leaf 36^1a. In this position of elements, the leaf 36^1a is held in its outwardly swung position and the tab 46 in its extended position, as shown in Figure 2. For that purpose the protuberance 56^1, the leaf 36^1a, the crank 54, and the rod 56 form a rigid truss structure by virtue of the fact that the forward end of the rod is anchored by its pivotal connection to the link 28, and the forward end of the leaf 36^1a is anchored by its pivotal connection to the end of the tube 36.

An outwardly projecting cam element 60 on the leaf 36^1a has a sloping surface interposed in the path of the protuberance 56^1 and engaged thereby when the rod 56 is moved rearwardly by the actuator 58. By moving the link 28 rearwardly of the engine, the crank 54 causes the tab 46 to swing forwardly and outwardly into contact with the inside face of the leaf 36^1a, and the protuberance 56^1 advances into contact with the cam 60. When the tab 46 contacts the leaf as in Figure 5, with the protuberance 56^1 then bearing against the cam 60, the leaf is swung inwardly to its position shown in Figure 5 by virtue of such cam engagement. The leaf is rigidly held in this position by the rigid truss structure formed by the protuberance 56^1, the cam 60, the leaf 36^1a, the crank 54, and the rod 56.

In the setting of the parts shown in Figures 4 and 5, the contracted nozzle exit is defined by the inwardly deflected leaves 36^1a and 36^1b, and the opposite surface of the tail cone 38 and is of generally annular form uninterrupted by noise suppression tabs. This represents the maximum thrust or cruise setting of the nozzle. The orifice opening yielding that result may be readily determined by well known jet engine design considerations. In the position of the parts shown in Figure 2, the nozzle exit is expanded by outward deflection of leaves 36^1a and 36^1b in order to compensate for for the decrease of exit opening area otherwise produced by extension of the noise suppression tabs 46 across the opening. It is found that the angle of swing of the leaves should be such that the nozzle exit opening is approximately the same with the tabs extended as it is with the tabs retracted. In this manner any reduction of nozzle efficiency when the noise suppression tabs are extended is minimized.

It will be noted that the actuating mechanism shown in this first-described embodiment of the invention produces automatic coordination between the setting of the noise suppression tabs and that of the leaves determining the area of the nozzle exit. However, it will be evident that for broad purposes the tabs may be actuated independently of the means for varying nozzle exit opening. With the type of actuating and connecting mechanism shown in this embodiment it will be apparent that the leaves are actuated conjointly between their alternative positions as are the tabs.

The described mechanism is of lightweight construction, enables the nozzle to be of circular form for purposes of compactness and efficiency, and is readily adapted for installation on available engine types. While in the illustration twelve retractable noise suppressor tabs are employed and these are of trapezoidal form which project inwardly to a location near the tail cone 38, it will be evident that a different number of tabs may be used and that their specific form or shape may vary. The form of the invention shown in Figures 1 to 9, inclusive, is also applicable to engines which do not have a tail cone such as the tail cone 38 in the illustration, inasmuch as the support of the

tabs and the compensating movement of duct-forming parts defining the nozzle exit does not depend upon the presence of a tail cone in this form.

Figures 10, 11 and 12 show modified tab forms in a noise suppression nozzle mechanism generally similar to that shown and described in connection with Figures 1 to 9, inclusive. In Figure 10, the tab 146 is basically of trapezoidal form and in all represents similar to the tab 46 shown in Figure 9, but is provided with flanges 146*a* and 146*b* which extend along the longitudinal edges of the tab and project rearwardly therefrom in the tab's extended position. These edge flanges on the tab form the sides of a channel by which outside air moving relatively along the outer cowl to the rear of the engine may move readily inwardly along the back side of the tab to regions within the discharge stream from the nozzle. This increases the effective mixing surface areas around the branch streams flowing between the tabs. The result is to promote mixture of the hot discharge gases and relatively cool outside air before the branch or divisional streams recombine. Mixture of ambient air with the gases in smaller streams produces less turbulence noise than it does when the mixture takes place with a large gas stream representing the total volume of the branch streams. Moreover, mixture of ambient air with a relatively small gas stream produces noise at higher, hence less objectionable frequencies, than it does with a relatively large stream.

In the modification shown in Figure 11, the tab 246 is of flanged construction as in Figure 10, but the web or body of the tab is provided with a number of small apertures 246*c*. These apertures pass some of the hot gases from the engine for admixture with cool outside air flowing inwardly across the rearward face of the tab between the flanges 246*a* and 246*b*. This arrangement further reduces engine noise, apparently for the reason that it warms the inwardly flowing outside air before its mixture with the divisional streams flowing between the tabs, so that the noise-producing turbulence of the mixture of such streams with the outside air is lessened. Also, there may be the additional effect of hot gases blowing through the apertures 246*c* imparting a rearward component of motion to the inwardly flowing outside air so that when it passes over the lips of the flanges and into contact with the gas streams, it is already moving rearwardly with appreciable velocity. As a result, the reduced differential rearward speed of the hot gases and the outside air when they first come together lessens the turbulence of their mixture and thereby further reduces the attendant noise. A jet propulsion engine having stream divider elements as shown in Figure 11 forms the subject matter of co-pending Application No. 26364/60 (Serial No. 859,994) which was divided out of the present application.

In the form shown in Figure 12, the tab 346 is troughed in the form of a V, the sides of which diverge rearwardly of the nozzle with the tab in its projected position as shown in Figure 12. The supporting leaf 136^1*a* in this modification is preferably formed with a pocket which accommodates the tab in retracted position. Channelization of outside airflow across the rearward face of the extended tab occurs in this embodiment as in the flanged configurations of Figures 10 and 11. Moreover this V-trough configuration of the tab gives it a streamline effect somewhat lessening its resistance to gas discharge through the nozzle opening in comparison with the flat tab configurations, and nozzle efficiency is somewhat increased in the noise suppression setting.

In the embodiment illustrated in Figures 13, 14 and 15, the retractable noise suppression tabs 446 are mounted on the tail cone 138 rather than on the tube forming the outer duct wall. As before, these tabs are of generally trapezoidal form and in this case are pivotally mounted to swing about their narrow ends on transverse pivot pins 60. The tabs may be otherwise generally similar to those used in the previously described embodiments. In their retracted positions, the tabs lie substantially flush with the surface of the tail cone, being received in the pockets 62. Movement of the tabs between their retracted and extended positions is effected by provision of a crank arm 64 fixed to the hinged end of the tab in general alignment therewith. This crank arm is connected by a rod 66 to a traveling nut 68 threaded on a drive screw 70 rotatably mounted in the tail cone to extend along the axis of the engine. Suitable means not shown rotating the drive screw causes the nut 68 to travel lengthwise thereof, hence, through the rod 66, swings the tab between its desired limits of travel. In this embodiment, generally the same means may be used for varying the effective nozzle exit opening as in the preceding embodiments, namely, a leaved section mounted on the rear end of the tube 36. In this case the leaves 136^1*a* have rigid crank arms 72 on their forward ends individually connected by a bar 74 to the guided link 28. The latter is moved lengthwise by the actuator 58 as before in order to swing the leaves inwardly or outwardly to the desired positions for area compensation. Such actuation may be coordinated automatically with rotary movement of the drive screw 70, or these operations may be independently controlled. An outer cowl 10^1 of constant configuration may

be employed in this example in the absence of a thrust reverser sleeve.

Figures 16 and 17 illustrate an embodiment in which the tabs 546 are mounted on the tube forming the outside wall of the duct and wherein such outside wall 136 is of fixed diameter at the exit whereas the tail cone 238 is longitudinally movable in order to vary the exit opening for area compensation purposes. In this case, the tail cone 238 extends forwardly into a cylindrical section which telescopes slidably within the tabular member 140. Longitudinal movement of the tail cone is effected by means of a drive screw 76 engaged by a nut 80, the latter being supported centrally within the tail cone unit by means of arms 82. Crank arms 72¹ connected to the pivoted ends of the tabs 546 are in turn connected by rods 74¹ to the individual guided links 28. The latter are moved longitudinally by the actuators 58 in order to retract and extend the tabs as desired. With the tabs retracted as in Figure 17 the tail cone will be moved rearwardly to its projected position, and by virtue of the taper of the tail cone will constrict the orifice exit (i.e. the opening between the rear edge of duct tube 136 and the nearest opposing surface of the tail cone) in order to produce maximum thrust from the engine. In order to extend the tabs as in Figure 16 for noise suppression purposes, the tail cone is drawn forwardly and by virtue of its rearward taper expands the exit opening in order to compensate for the area reduction produced by the extended tabs. Thus, as in the previous embodiments, the effective orifice exit opening is maintained substantially constant in either of the nozzle settings. As before, co-ordination of movement of the tabs and of the means varying the orifice opening for compensation purposes may be employed, or they may be independently operated.

In the embodiments shown in Figures 18 to 22, inclusive, the desired orifice area compensation is achieved by contraction and expansion of a leaved ring section similar to that employed in Figures 13 and 14, but in this instance a different type of stream divider or obstruction element is used in lieu of the retractable tab of the preceding embodiments. In this instance, the tail cone 338, if incorporated in the engine, is required to be slotted to permit travel fore and aft of a vane assembly consisting of the radially projecting vane supports 84 and the pairs of vanes 85 hingedly mounted on the respective rear edges thereof to swing between mutually abutting retracted position shown in Figure 21, and rearwardly divergent or laterally extended position shown in Figures 18 and 22. The supporting hinges 86 for these vanes are inclined forwardly and outwardly in relation to the engine so that the obstructive or stream-dividing wedge presented to the discharge stream by a pair of vanes in extended position will have materially greater width at the nozzle periphery than it does at the core for promoting inflow of ambient air for admixture with the branch streams. Another reason for the inclination of the hinge axis is to permit the vanes to extend radially outwardlly a maximum distance from the engine axis without encountering interference from the surrounding leaved extension of duct tube 36 when the pairs of vanes are extended.

In order to permit the vanes to extend outwardly substantially to the edge of the jet stream in the noise suppression setting of the nozzle, without their interfering with contraction of the nozzle orifice to the cruise setting by inward movement of the leaves 136¹*a* and 136¹*b*, the vane assembly including the vane supports 84 may be drawn forwardly, as shown in Figure 19. Conversely, the vane assembly is projected rearwardly into the position shown in Figure 20 for the noise suppression setting when the vanes are extended. Such longitudinal movement of the vane assembly is effected by mounting the vanes on an inside conical support 87 having a nut 88 therein which engages a drive screw 89 rotated by suitable drive means not shown. The pairs of vanes are actuated between extended and retracted positions by hydraulic actuators 89 working through a lever 90, a rod 91 connected by a slot and pin to the end of the lever, and a toggle linkage 92 pivotally connected to the rod. The lever 90 and its support 90*a*, the rod 91, and the toggle linkage are supported by and within the faired vane support 84 and partially in the space between the vanes 85. The actuator 89 is suitably mounted on the assembly carrying the vane supports as shown.

In the embodiment of Figures 18 to 22, the vanes remain in the nozzle orifice opening at all times. However, in their retracted position as in Figure 21 each pair of vanes co-operates with its support to form a streamlined element which permits the discharge gases in the regions between pairs of vanes to recombine before emerging from the nozzle exit. Consequently, such elements have little or no effect on nozzle thrust or noise level with the vanes retracted. On the other hand, when such vanes are laterally extended as in Figure 22 the main discharge leaves the nozzle exit in a plurality of branch streams which are separated by the spacing between the trailing edges of the vanes of each pair and into these spaces surrounding ambient air is drawn for mixing with the smaller gas streams as desired for low noise operation of the engine.

It will therefore be evident that the invention has various forms and embodiments

the preferred of which are herein shown and described and which in themselves possess certain unique features and special advantages. It will also be apparent that in its broader aspects the invention is not confined to the details of illustration employed herein for purposes of explanation.

WHAT WE CLAIM IS:—

1. In a jet propulsion engine of the gas stream thrust reaction type having duct means with an exit for discharge of gases rearwardly from the engine to create forward thrust, nozzle means to reduce engine noise comprising a plurality of stream divider elements having an extended position disposed generally across the path of discharge, support means mounting said elements at successively spaced locations transversely to the direction of discharge and to permit movement thereof between the extended position of said elements separated from each other at the exit thereby to divide said gas stream into a plurality of substantially separate smaller streams, and the retracted position disposed to permit discharge of said stream undivided by said elements, means for actuating said elements between extended and retracted positions thereof, said nozzle duct means comprising elements forming the nozzle exit opening and adapted for relative movement to vary the area of said exit opening, and actuating means connected to said duct means to effect relative movement of said duct means elements for increasing the area of said opening to an extent at least partially compensating for the effective reduction of such area inherently produced by the extension of the stream divider elements.

2. The jet propulsion engine defined in Claim 1, and means limiting relative movement of the duct means elements at relative positions increasing the exit opening area by substantially the same amount as the effective decrease of area thereof produced by extension of the stream divider elements.

3. The jet propulsion engine defined in Claim 1, wherein the duct means is of annular form, the stream divider elements are mounted at successively spaced locations therearound, and in the extended position said elements extend generally radially of the duct means, dividing the gas stream into radially extending branch streams.

4. The jet propulsion engine defined in Claim 3, wherein the annular duct means comprises a succession of inwardly and outwardly swingable leaves hinged at their forward edges to vary the duct opening, and the stream divider elements comprise generally plate-like elements pivotally mounted on certain of the leaves to swing about axes generally transverse to the direction of discharge from the engine, between the outwardly swung retracted position extending generally parallel to their respective supporting leaves and inwardly swung extended position generally perpendicular to such leaves, and means for actuating said plate-like elements to the extended position with the leaves swung outwardly, and to the retracted position with the leaves swung inwardly.

5. The jet propulsion engine defined in Claim 1, wherein the stream divider elements comprise plate-like elements pivotally mounted on the duct means to swing about axes generally transverse to the direction of discharge from the engine, between retracted position extending in a plane generally parallel to the direction of discharge and extended position generally perpendicular thereto, and means for actuating said plate-like elements for movement between such positions.

6. The jet propulsion engine defined in Claims 1 or 5, wherein the duct means is of annular form and comprises a succession of inwardly and outwardly swingable leaves hinged at their forward edges to vary the duct opening, and the plate-like stream divider elements are of generally trapezoidal form having base ends pivotally mounted on their respective supporting leaves.

7. The jet propulsion engine defined in Claim 6, wherein the plate-like stream divider elements have opposite side portions extending radially thereof and projecting generally rearwardly in relation thereto in the extended position of such elements, said side portions channelling indrawn ambient air to flow between them radially inwardly of the engine across the rear face of each such element, thereby to promote low noise mixture of such air with the separate gas streams separated by the successively located stream divider elements.

8. The jet propulsion engine defined in Claim 6, wherein the plate-like stream divider elements are of troughed rearwardly open form channelling indrawn ambient air radially inwardly of the engine across the rear face of each such element within its trough with the elements extended, thereby to promote low noise mixture of such air with the separate gas streams separated by the successively located stream divider elements.

9. The jet propulsion engine defined in Claim 7, wherein said stream divider elements have opening therein permitting restricted rearward flow of engine gases through them for admixture with inwardly channelled ambient air flowing across the rearward faces of such elements.

10. The jet propulsion engine defined in Claim 1, wherein the nozzle duct means comprises a central tail cone element tapering rearwardly of the nozzle and a tubular element surrounding said tail cone, and means adapted to effect relative longitudinal

movement between said tail cone element and said tubular element to vary the overlap of said tubular element in relation to the tapered portion of said tail cone element, thereby to vary the area of said opening to an extent permitting at least partially compensating for the effective reduction of such area inherently produced by the extension of the stream divider elements.

11. The jet propulsion engine defined in Claim 10, wherein the stream divider elements comprise generally plate-like tabs mounted at intervals around the periphery of one of the duct means elements to swing about generally tangential axes in relation thereto, respectively, between retracted position extending generally fore and aft and extended position disposed generally crosswise to the nozzle discharge in the path thereof.

12. The jet propulsion engine defined in Claim 1, wherein the stream divider elements individually comprise a support projecting transversely acrose the nozzle discharge and a pair of vanes having forward edges pivotally secured to said support on respectively opposite sides thereof, said vanes of each pair being adapted for movement by said actuating means between laterally abutting retracted position and rearwardly divergent extended position.

13. The jet propulsion engine defined in Claim 12, wherein the nozzle duct means comprises a tubular member having a substantially circular cross section, and a rearward extension of said tubular member comprising a plurality of longitudinally extending leaves hingedly connected by their forward edges to said tubular member for swinging inward and outward in relation to the engine axis, thereby to vary the exit opening, the vanes and vane supports extending generally radially within said duct means.

14. The jet propulsion engine defined in Claim 13, wherein the vanes extend radially outward substantially to the periphery of the rear or exit end of the leaved extension in the outwardly swung position of the leaves, and means to move the vane supports longitudinally of the engine to permit inward swinging of such leaves to constrict the exit opening.

15. The propulsion engine defined in Claim 14, wherein the forward edges of the vanes are inclined outwardly and forwardly in relation to the nozzle, whereby relative swinging of the vanes of each pair away from each other produces greater proportional separation between such vanes at their radially outer ends than at their radially inner ends, in relation to the corresponding proportional separation thereof in the laterally abutting position of the vanes.

16. In a jet propulsion engine of the gas stream thrust reaction type, a noise suppression discharge nozzle comprising duct-forming means defining a nozzle discharge orifice having an exit, said duct-forming means including elements relatively movable to increase and decrease the effective orifice cross-sectional area through which the discharge is confined, a plurality of stream divider elements adapted for movement between the extended position disposed obstructively in the path of and transversely to the discharge through said orifice, said elements being spaced apart transversely of the discharge in said orifice for diving such discharge into separate streams at said orifice exit, thereby to effect engine noise reduction, and the retracted position disposed substantially non-obstructively in relation to said discharge, thereby to recover maximum thrust from the nozzle, means to move said divider elements between such positions, and means to move said relatively movable duct-forming elements to increase the orifice cross-sectional area with said divider elements extended obstructively, thereby to compensate for the reduction of orifice area caused by the obstructive effect of the extended elements, and correspondingly to decrease said orifice area with said divider elements retracted.

17. The engine defined in Claim 16, wherein the duct-forming means comprises an annular sleeve having a rear end portion including a plurality of sleeve-forming segments which overlap successively around the sleeve periphery and which are pivotally supported to swing in and out.

18. In a jet propulsion engine of the gas stream thrust reaction type, a noise suppression discharge nozzle comprising retractable means dividing the discharge of said nozzle into a plurality of smaller streams discharged therefrom with spacing therebetween permitting inflow of surrounding air therebetween for admixture with the discharge gases while in said separate streams, and retractable means operable to combine said gases into a single large stream for discharge from said nozzle with at least approximately the same cross-sectional area as the total cross-sectional areas of said seperate streams.

19. A jet propulsion engine substantially as described and as shown in the accompanying drawings.

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 COMPLETE SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

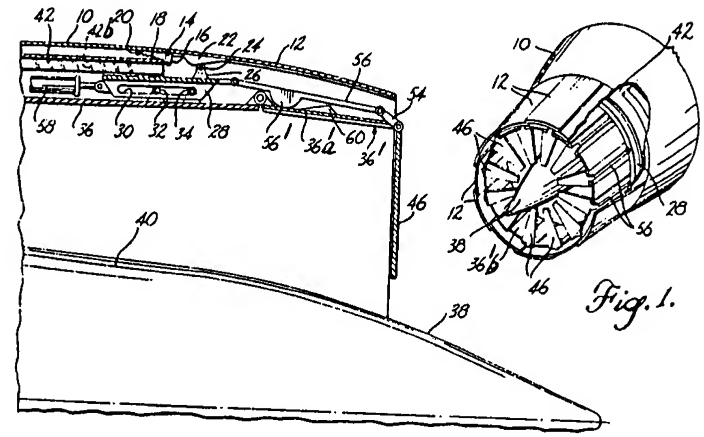

Fig. 2.

Fig. 1.

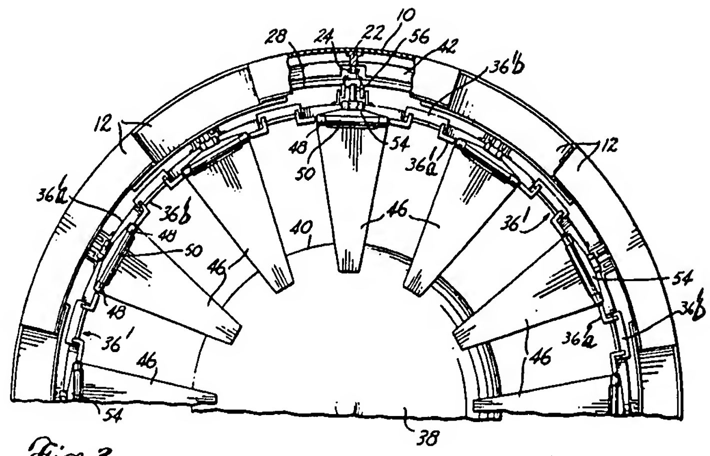

Fig. 3.

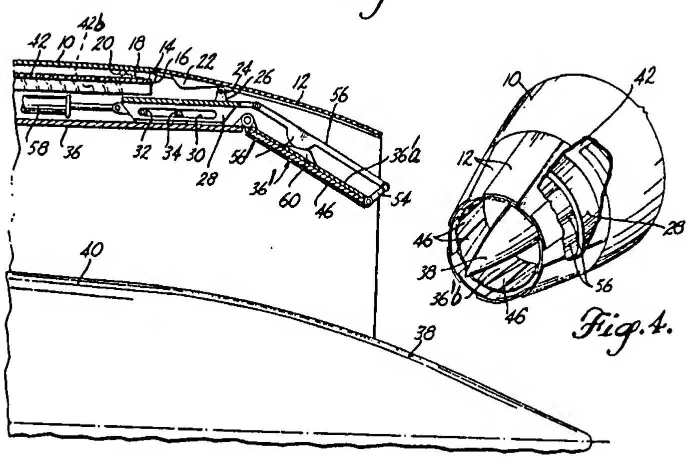

Fig. 5.

Fig. 4.

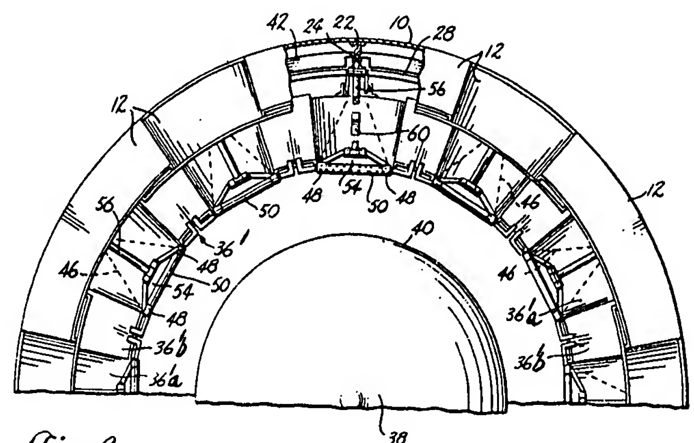

Fig. 6.

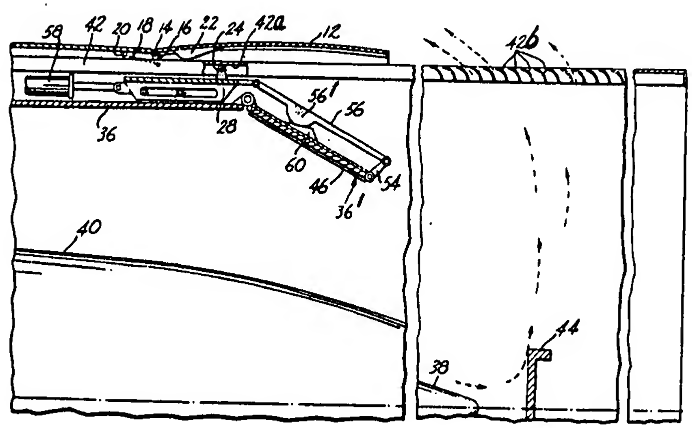

Fig. 8.

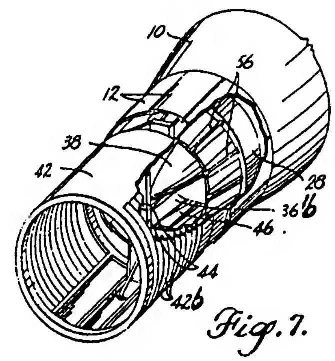

Fig. 7.

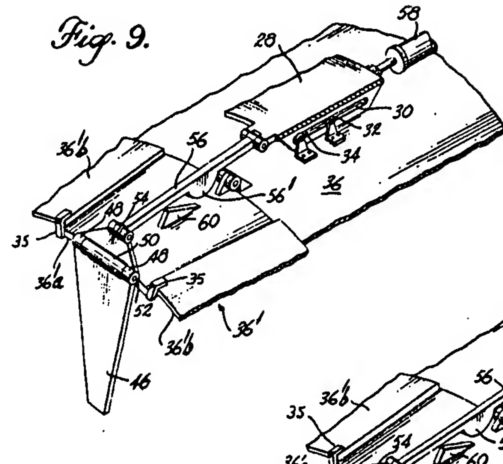

Fig. 9.

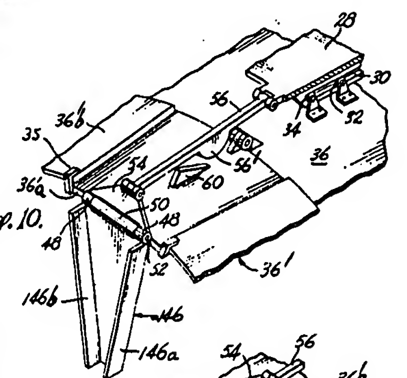

Fig. 10.

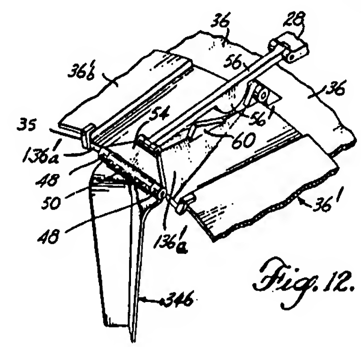

Fig. 12.

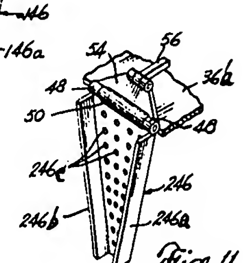

Fig. 11.

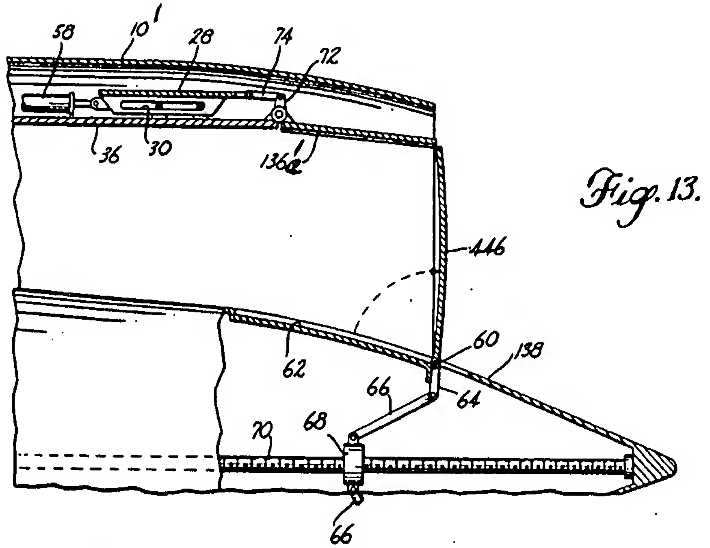

Fig. 13.

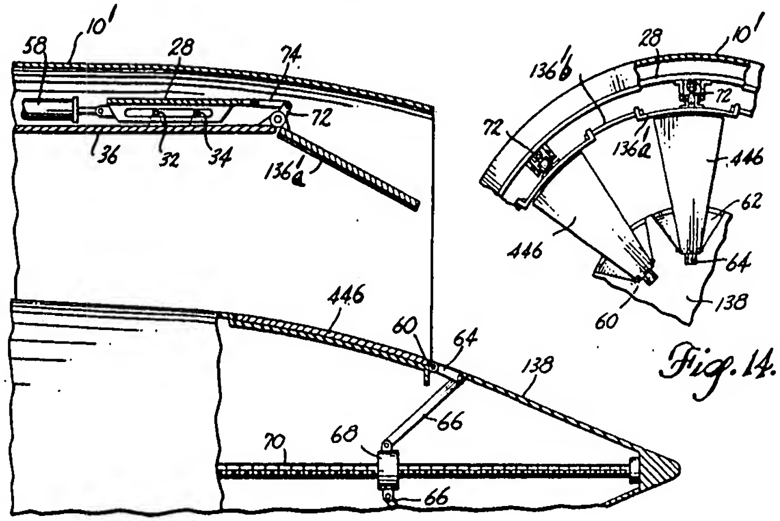

Fig. 15.

Fig. 14.

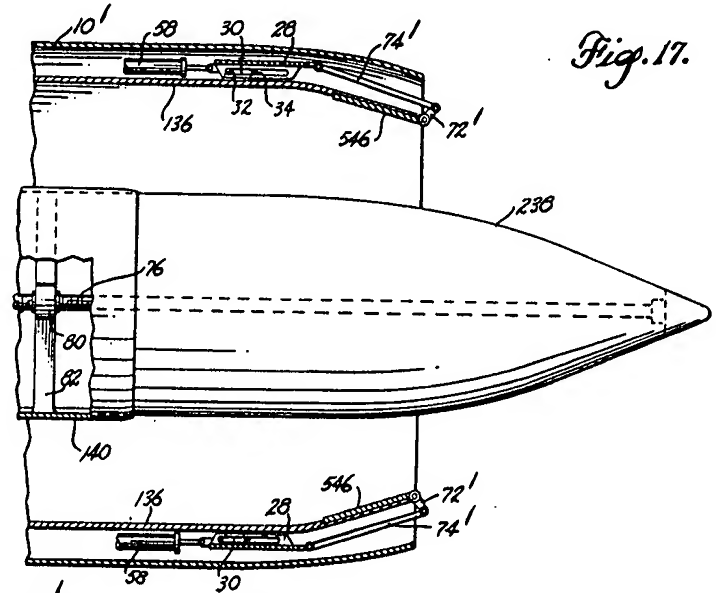

Fig. 17.

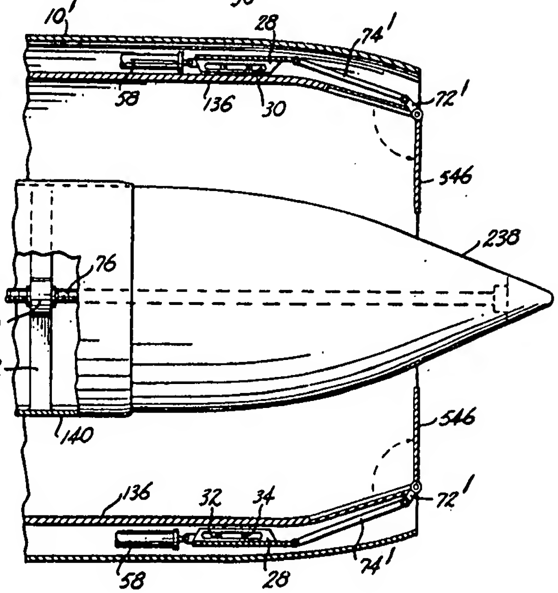

Fig. 16.

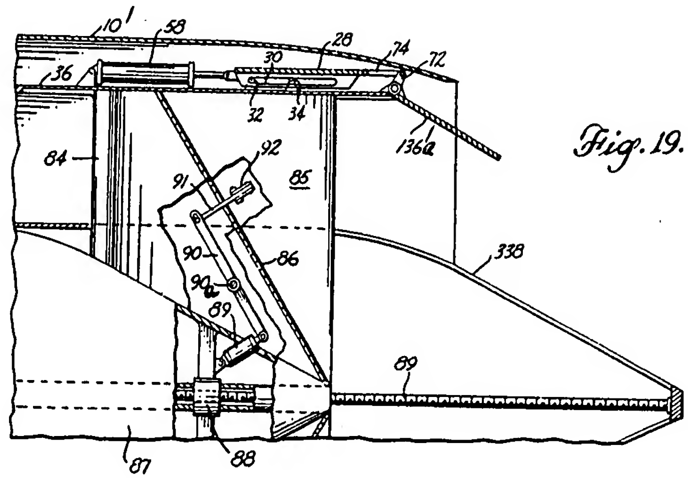

Fig. 19.

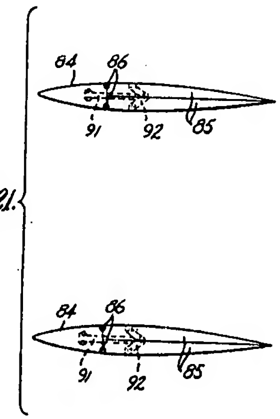

Fig. 21.

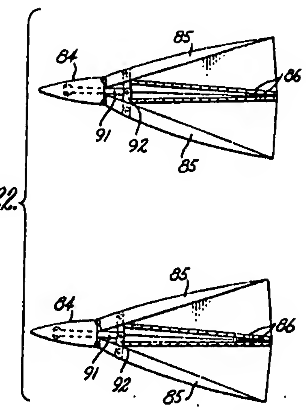

Fig. 22.

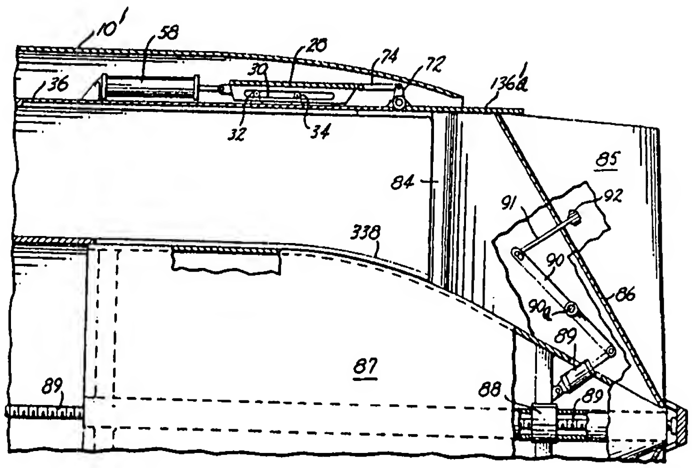

Fig. 20.

Fig. 18.